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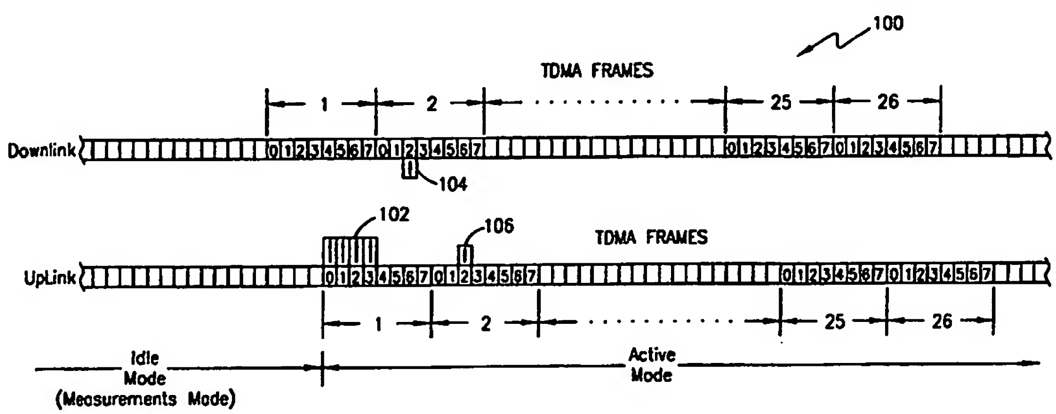


(57) Abstract

When a mobile terminal (12) first switches over from the idle mode (powered on and waiting to set up for a call) to the active mode (call connected), it starts sending measurement information to the network as soon as a dedicated traffic channel is assigned. In the preferred embodiment, the first measurement report is transferred to the network during the first available slow associated control channel period. That first report to the network contains data that the mobile terminal (12) obtained while it was waiting in the idle mode. During subsequent slow associated control channel periods, the mobile terminal (12) transfers measurement information to the network based on the data obtained in the active mode.

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# METHOD FOR REPORTING MEASUREMENT INFORMATION IN A MOBILE COMMUNICATIONS SYSTEM

## BACKGROUND OF THE INVENTION

### Technical Field of the Invention

The present invention relates in general to the mobile telephony field and, in particular, to a method for use in improving measurement reporting in a mobile communications system.

### Description of Related Art

Given the advent of such complex, high-performance frequency allocation schemes as multiple reuse patterns (MRP) in mobile telephony systems, the frequency planning process has become increasingly arduous for mobile communications network operators. Consequently, in response to the growing need for automated frequency planning schemes, a new frequency planning algorithm for cellular communications systems called "Automatic Frequency Allocation" (AFA) has been developed by Telefonaktiebolaget L M Ericsson (publ). AFA is seen as a suitable technique for simplifying frequency planning, while still allowing operators to obtain system capacities that are very close to what can be obtained with manual MRP schemes.

Generally, AFA utilizes an iterative algorithm, which automatically and frequently reconfigures a network's cell plan (to minimize radio interference) and gradually improve the quality of the radio environment. The basic idea behind the AFA approach to frequency planning is that each cell in the network monitors the signal strength on all (or a subset of all) frequencies available to the operator. The signal strength measured on each frequency is utilized to estimate the interference that would be generated if that frequency were to be used. If any non-allocated frequency has a lower estimated interference than that of an allocated frequency, a frequency switch is made. Thus, the allocated frequencies with the highest interference are replaced by the frequencies with the lowest estimated interference. The AFA algorithm repeats this

procedure (iteratively) until no further improvement (in terms of the carrier-to-interference ratio or C/I) can be obtained.

Arguably, for frequency planning purposes, it is sufficient to measure signal strength on the uplink only, since these measurements would indicate generally those frequencies that carry traffic. However, there are at least two very important reasons why signal strength should also be measured on the downlink. First, for optimum frequency planning, the interference environment should be surveyed in the cells where most of the signal traffic occurs.

One technique that can be used is to measure the downlink interference at the base station that defines the cell. However, since this measurement is being made at only one point (e.g., where the measurement receiver's antenna is located), this lone reading is wholly inadequate from a testing and operational standpoint.

Another technique that can be used is to place interference measurement equipment at a number of different, fixed locations in a cell. Consequently, the downlink interference in the cell could be measured at all of those locations. However, this approach requires the purchase of a substantial amount of measurement equipment, which is quite costly to install and maintain. In fact, this added cost would outweigh the potential benefits that could be derived from making the downlink interference measurements at the numerous locations in the cell. As mentioned earlier, in order to obtain the best results with such a downlink measurement approach, the measurement equipment should be located where the majority of the cell traffic occurs, but the network operator typically does not have such knowledge beforehand.

Second, most of today's cellular communications systems utilize sectorized (uni-directional) cell antennas to improve network performance. However, uplink measurements that are made at a cell's base station do not detect traffic outside the base station antenna's sector. In other words, the radio interference created by mobile terminals located in the area behind that sector cell's base station antenna is not detected.

In the digital cellular Global System for Mobile Communications (GSM), the downlink measurements are required to be performed by the mobile terminals. Typically, there is ample time for the mobile terminals to conduct the downlink

measurements while operating in the idle mode, but the transfer of all of the terminals' measurement results to the base station should be accomplished in a manner so as to occupy as little of the system's resources (e.g., allotted frequency spectrum) as possible.

In existing cellular communications systems (e.g., GSM), signal strength measurements collected by a mobile terminal while operating in the idle mode are utilized by the mobile terminal only during the idle mode. On the other hand, measurements collected by the mobile terminal while operating in the active mode are transferred (reported) to the network during the active phase of the connection. However, a problem with the existing systems is that the measurements collected by the mobile terminals in the idle mode are not reported to the network at all. In fact, until now, there has been no requirement for the mobile terminals to report their idle mode measurements to the network. Consequently, there has been no defined approach for the mobile terminals to use in order to communicate their idle mode measurements to the network. Therefore, in order for the network to base any decisions about the radio environment on the downlink measurement data, the network has to use the measurement data reported by the mobile terminals operating in the active mode. This active mode measurement data is reported to the network primarily for the purpose of controlling handovers and regulating the power of specific radio connections.

A problem arises if the active mode measurement data is to be used for purposes other than handover control and power regulation, because conflicting requirements can be placed on the data to be collected. For example, the handover control function requires the use of downlink signal strength measurement data from the neighboring cells that are immediately adjacent to the serving cell. On the other hand, the frequency allocation control function requires the use of downlink signal strength measurement data from distant neighbors. Such a conflict in the use of the downlink signal strength measurement data can lead to compromises in defining which cells to measure, which decreases the performance of both functions. An additional but related problem is that a mobile terminal operating in the active mode does not have as much time to perform measurements as a mobile terminal operating in the idle mode.

Notably, if measurements performed by mobile terminals operating in the idle mode could be used by the network, there would be a greater degree of freedom available for the network operator to select the parameters to measure, since the mobile terminals would have much more time available to perform the measurements than they would in the active mode. However, it is currently not possible to transfer this measurement information to the radio network control entity, without introducing extra measurement report messages that would place an additional load on the air interface.

## SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to enable mobile terminals to transfer measurement information to the network without increasing the air interface load or reducing system performance.

It is also an object of the present invention to enable the use of downlink interference estimates based on signal strength measurements for automatic or adaptive frequency planning purposes.

It is yet another object of the present invention to enable a network to use information that was obtained by mobile terminals waiting in the idle mode.

It is still another object of the present invention to give a network operator more flexibility in selecting parameters to measure.

In accordance with the present invention, the foregoing and other objects are obtained by a method which enables a mobile terminal to switch over from the idle mode (powered on and waiting to set up for a call) to the active mode (call connected), and start sending measurement information to the network as soon as a dedicated traffic channel is assigned. In the preferred embodiment, the measurement data is transferred to the network on the slow associated control channel. The first report of measurement information, which is transferred to the network during the first available slow associated control channel period, contains data that the mobile terminal obtained while it was waiting in the idle mode. Subsequently, the mobile terminal transfers measurement information to the network based on the data obtained in the active mode.

## BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a block diagram of an exemplary mobile communications system that can be used to implement the present invention; and

FIGURE 2 is a diagram that illustrates the downlink and uplink frame formats for a cellular communications system using a time division multiple access (TDMA) scheme, in accordance with the preferred embodiment of the present invention.

## DETAILED DESCRIPTION OF THE DRAWINGS

The preferred embodiment of the present invention and its advantages are best understood by referring to FIGUREs 1-2 of the drawings, like numerals being used for like and corresponding parts of the various drawings.

As described earlier, when a GSM mobile terminal first connects to the network, the mobile terminal has no prior knowledge about the timing of the slow associated control channel (SACCH) period. As such, GSM mobile terminals are frequently connected to their network near the middle of a SACCH period, and the measurements performed during the remainder of this period are thus incomplete. Consequently, the first measurement data reported to the network is not useful. As described below, mobile terminals operating in accordance with the present invention advantageously make use of the first complete SACCH period to provide useful measurement data to the network.

Essentially, in accordance with the preferred embodiment of the present invention, when an active connection is first set up between a mobile terminal and network base station, the mobile terminal starts sending measurement reports to the network as soon as a dedicated channel is assigned. The measurement information is transferred to the network on the slow associated control channel. The first measurement report, which is transferred to the network during the first complete slow associated control channel period on the dedicated channel, contains measurement data that the mobile terminal obtained while it was waiting in the idle mode. During the

subsequent slow associated control channel periods, the mobile terminal transfers measurement information based on data obtained in the active mode.

Specifically, FIGURE 1 is a block diagram of an exemplary mobile communications system 10 that can be used to implement the present invention. For this embodiment, the exemplary system (10) shown is the cellular GSM, but this example is for illustrative purposes only, and the invention is not intended to be limited to any particular mobile communications system. In fact, the inventive concept can also be applied to cover other telecommunications fields, such as, for example, satellite communications wherein a mobile terminal first makes an active connection on the uplink in a satellite communications system. Cellular system 10 can include a plurality of mobile terminals (exemplified by the one mobile terminal 12 shown), which communicate with a Base Transceiver Station (BTS) antenna 14 via a radio air interface. BTS antenna 14 defines the coverage of one cell in the mobile network of system 10. A plurality of BTSs (not explicitly shown) including BTS 14 is controlled by a Base Station Controller (BSC) 16, which controls such functions as handovers and channel assignments in the cellular network. A plurality of BSCs (not explicitly shown) are connected to a Mobile Services Switching Center (MSC) 18, which controls calls to and from other telephony and data communications systems (not explicitly shown), such as, for example, a Public Switched Telephone Network (PSTN), Integrated Services Digital Network (ISDN), Public Land Mobile Network (PLMN), Public Data Network (PDN), or one or more private networks. In the GSM, for example, if someone in a PSTN wants to call a GSM subscriber (12), the exchange in the PSTN connects the call to a gateway. If the gateway is realized in MSC 18, then MSC 18 is referred to as a Gateway MSC (GMSC). MSC 18 is connected to a Visitor Location Register (VLR) 20, which is a database that contains information about all of the mobile terminals (12) currently located in that MSC's area. MSC 18 is also connected to a Home Location Register (HLR) 22, which is the network's primary database. HLR 22 contains subscriber information, such as supplementary services and authentication parameters, and information about the location of the subscriber's mobile terminal (e.g., in which MSC area the mobile terminal currently resides).

Generally, in the GSM, signal strength measurements are made in both the idle mode (e.g., while the mobile terminal is switched on and moving around) and the active mode. The initial cell selection is made when mobile terminal 12 is first "powered on". At power on when entering the idle mode, mobile terminal 12 scans all radio frequencies allocated to the GSM, and calculates the average signal strength level for each of those frequencies. The mobile terminal tunes to the strongest (highest average level) carrier and determines whether it is a Broadcast Control Channel (BCCH) carrier. In the GSM, the mobile terminal determines this by searching for the frequency correction burst, which is sent in time slot "0" on the BCCH carrier. If the strongest carrier is a BCCH carrier, the mobile terminal attempts to synchronize to this carrier and read the BCCH data (e.g., system information messages). If the mobile terminal can decode the BCCH data successfully and the data indicates that the cell is suitable, then the mobile terminal locks onto or "camps on" this cell. In the GSM, a cell is "suitable" if: (1) the cell belongs to the PLMN selected; (2) the cell is not barred from access; and (3) the path loss criterion, C1, is larger than "0". Otherwise, the mobile terminal tunes to the second strongest carrier, and so on, to search for a suitable cell.

Also, while in the idle mode, the mobile terminal (12) stays in a "sleep" mode, except when it is scheduled to listen for paging messages (or decode the BCCH information). In the GSM, all system information messages conveyed on the BCCH are read at least once every thirty seconds, in order to monitor changes in cell parameters (e.g., the cell might have become barred in the meantime). While listening to its own paging group for paging messages, the mobile terminal (12) takes measurement samples on certain frequencies allocated to predefined neighboring cells. In the GSM, the mobile terminal is required to take at least five measurement samples for each predefined neighboring cell. As such, the network transmits (e.g., via BTS antenna 14) a BCCH Allocation (BA) list on the BCCH, which informs mobile terminal 12 about which BCCH carriers it is to monitor (the predefined neighboring cells) for cell re-selection purposes. Mobile terminal 12 attempts to check the Base Station Identity Code (BSIC) for each of the six strongest of the predefined neighboring cells at least once every thirty seconds, in order to confirm that it is still monitoring the same cells. If the mobile terminal detects a change in a BSIC for a particular cell, then that

carrier is treated as a new carrier and the BCCH data for that new carrier is redetermined. While in the idle mode, the mobile terminal maintains an updated list of the six strongest neighboring cells, based on the signal strength measurements made.

FIGURE 2 is a diagram that illustrates the downlink (network side) and uplink (mobile terminal side) frame formats for a cellular communications system using a TDMA scheme, in accordance with the preferred embodiment of the present invention. For the sake of clarity and to facilitate understanding the invention, the exemplary frame formats shown in FIGURE 2 are described with respect to the standard GSM protocol, but the invention is not intended to be so limited. The invention can also be applied to any other type of cellular communications system that utilizes a TDMA scheme and mobile-assisted measurement procedures, such as, for example, the Advanced Mobile Phone Service (AMPS), Digital-AMPS (D-AMPS), Personal Digital Cellular (PDC) System, Personal Communications System (PCS), etc.

Referring to FIGUREs 1 and 2, and in accordance with the present invention, the mobile terminal 12 (and other mobile terminals in the system) make, at a minimum, signal strength and quality measurements for its own cell, and at least signal strength measurements for neighboring cells while in the idle mode. The mobile terminal averages these measurements and stores the measurement information and averages in a local memory location. In this embodiment (e.g., in the GSM), the MSC 18 initiates a call by sending a set up message to the mobile terminal (12). If the mobile terminal can handle the call, it sends a call confirmed message back to the MSC. The MSC (18) then initiates a procedure to assign a dedicated traffic (e.g., speech) channel to the mobile terminal (12). The BSC 16 selects an unused traffic channel and sends a Channel Activation message to the BTS 14, which responds by sending a Channel Activation Acknowledge message back to the BSC 16. The BSC 16 then sends an Assignment Command message (on the Stand-alone Dedicated Control Channel or SDCCH) to the mobile terminal 12 (via the air interface), which directs the mobile terminal to switch to the new traffic channel. In the GSM, this new traffic channel, which is to be dedicated for use by this particular mobile terminal (12), typically includes a dedicated traffic channel (TCH), a slow associated control channel or SACCH, and a fast associated control channel (FACCH). A SACCH is a data channel

associated with either a particular TCH or SDCCH and that continuously carries information. A FACCH is also associated with a particular TCH and works in the "burst-stealing" mode to replace speech or data traffic with signalling information.

In accordance with the present invention, as soon as the dedicated channel has been assigned and the connection between the mobile terminal 12 and BSC 16 has been set up, the mobile terminal transfers the stored measurement data (collected earlier while in the idle mode) to the network immediately during the next complete SACCH period (denoted by 102) on the dedicated traffic channel. As shown in this example, the GSM format typically utilizes a duration of four SACCH time slots to completely transfer measurement data. However, the invention is not intended to be so limited and can utilize more or less time slots than the four SACCH time slot duration shown (i.e., systems other than the GSM may use different time slot durations). Subsequently, after the idle measurement information has been transferred on the uplink (102), the mobile terminal (12) then begins to make measurements for reporting in the active mode.

For example, in the GSM, during the active mode time period denoted by 104, the mobile terminal 12 receives and measures the signal strength for its serving cell. During the active mode time period denoted by 106, the mobile terminal transmits the active mode signal strength measurement for its serving cell on the SACCH. Similarly, the mobile terminal then measures signal strength for at least one of the neighboring cells and stores that information for a subsequent transmission. The active mode measurements are continued thereafter for the duration of the call.

In one aspect of the preferred embodiment, the measurements made by mobile terminals in the idle mode can be used for automatic frequency planning. For example, as described earlier, AFA is an automated frequency planning technique that utilizes an iterative algorithm to automatically and frequently reconfigure a network's cell plan (to minimize radio interference) and gradually improve the quality of the radio environment. Basically, using an AFA approach, the uplink and downlink signal strengths for all available frequencies are monitored for each cell in the network. The measured signal strength on each frequency is used to estimate the interference generated if that frequency were to be used. If any non-allocated frequency has a lower estimated interference than an allocated frequency, the network switches over from the

allocated to the non-allocated frequency. The allocated frequencies with the highest interference are replaced by the frequencies having the lowest measured signal strength, and so on until no additional improvement in performance can be made. In accordance with the invention, the uplink measurements are made at the base stations, but the downlink measurements can now be made by the mobile terminals in the idle mode, which provides ample time to make an appropriate number of measurements.

As such, the mobile terminals can be ordered to make idle mode measurements in accordance with a specific procedure. For example, in the GSM, a list similar to the BA list of frequencies to be measured is broadcast to the mobile terminals. The mobile terminals can note those frequencies and make the required measurements while waiting in the idle mode. Alternatively, the idle mode measurement frequencies can be relayed to the mobile terminals by being "piggy-backed" on various signalling messages, such as, for example, one or more Location Updating messages.

In another aspect of the preferred embodiment, by measuring the downlink signal strength on any given BCCH carrier and "listening" for the corresponding BSIC, the invention makes it possible to detect the allocation of a "bad" BCCH. For example, if one or more mobile terminals are unable to decode the BSIC for a particular allocated BCCH, and the measured signal strengths are high for that BCCH, then the BCCH frequency can be assumed to have high interference and not suitable for use. Also, if the mobile terminals decode a BSIC for a BCCH other than the one anticipated, a problem with the BSIC allocation is indicated. Notably, if there is high enough interference on a BCCH such that the mobile terminals cannot decode the BSIC, this problem will not be recognized in the active mode measurement reports even if the signal strength is high. A similar problem exists if the BSIC can be decoded for a BCCH, but the signal strength is too weak for the measuring mobile to include that measurement in the active mode measurement reports to the network (where only the six strongest frequencies with decoded BSICs are included). Furthermore, similar to the problem of recognizing the allocation of a "bad" BCCH, if the signal strength measurement recorded for a BCCH carrier is strong, but the mobile terminals are unable to decode the BSIC, then the cell corresponding to that BCCH is not suitable to use as a neighboring cell. Consequently, these problems can be solved by sending

measurement reports to the network based on the measurements made by the mobile terminals while waiting in the idle mode.

Although a preferred embodiment of the method and apparatus of the present invention has been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

WHAT IS CLAIMED IS:

1. A method for use in reporting measurement information in a TDMA mobile communications system, comprising the steps of:

at least one mobile terminal of a plurality of mobile terminals measuring a plurality of downlink signal parameters while operating in an idle mode;

switching said at least one mobile terminal of a plurality of mobile terminals to an active mode; and

said at least one mobile terminal of said plurality of mobile terminals transmitting report information associated with said plurality of downlink signal parameters in a first available uplink data channel.

2. The method according to Claim 1, wherein said plurality of downlink signal parameters comprises a plurality of downlink signal strength parameters.

3. The method according to Claim 1, wherein said first available uplink data channel comprises at least one slow associated control channel.

4. The method according to Claim 1, wherein said TDMA mobile communications system comprises a GSM.

5. A system for use in reporting downlink measurement information in a TDMA mobile communications system, comprising:

at least one mobile terminal operable to measure a plurality of downlink signal parameters in an idle mode;

switching means for switching said at least one mobile terminal to an active mode; and

said at least one mobile terminal including transmitting means for transmitting report information associated with said plurality of downlink signal parameters in a first available uplink data channel.

6. The system according to Claim 5, wherein said plurality of downlink signal parameters comprises a plurality of downlink signal strength parameters.

7. The system according to Claim 5, wherein said first available uplink data channel comprises at least one slow associated control channel.

8. The system according to Claim 1, wherein said TDMA mobile communications system comprises a GSM.

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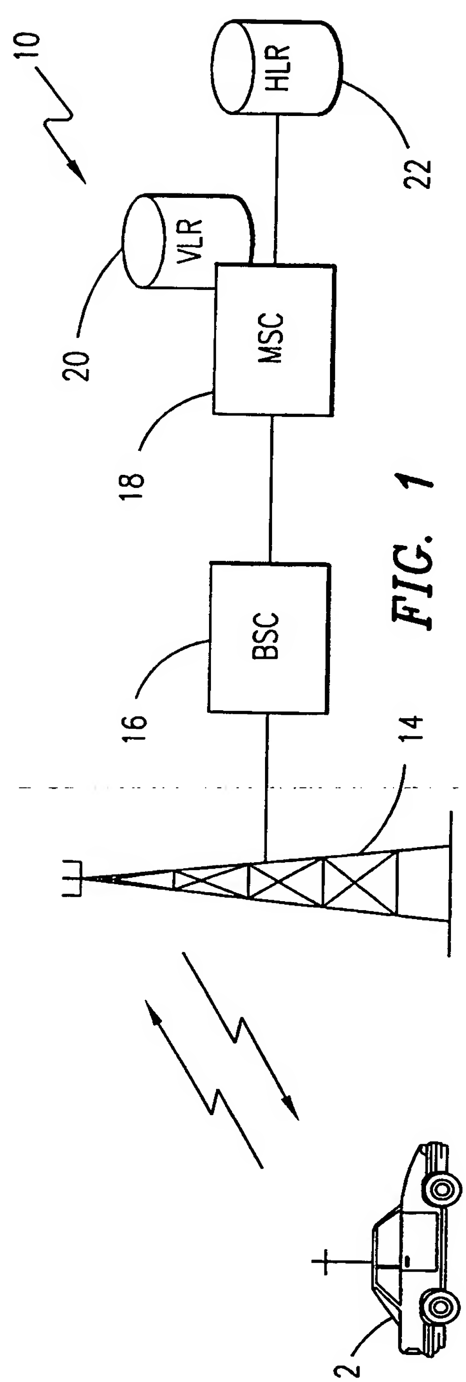
10
12
14
16
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18
MSC
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VLR
22
HLR

FIG. 1

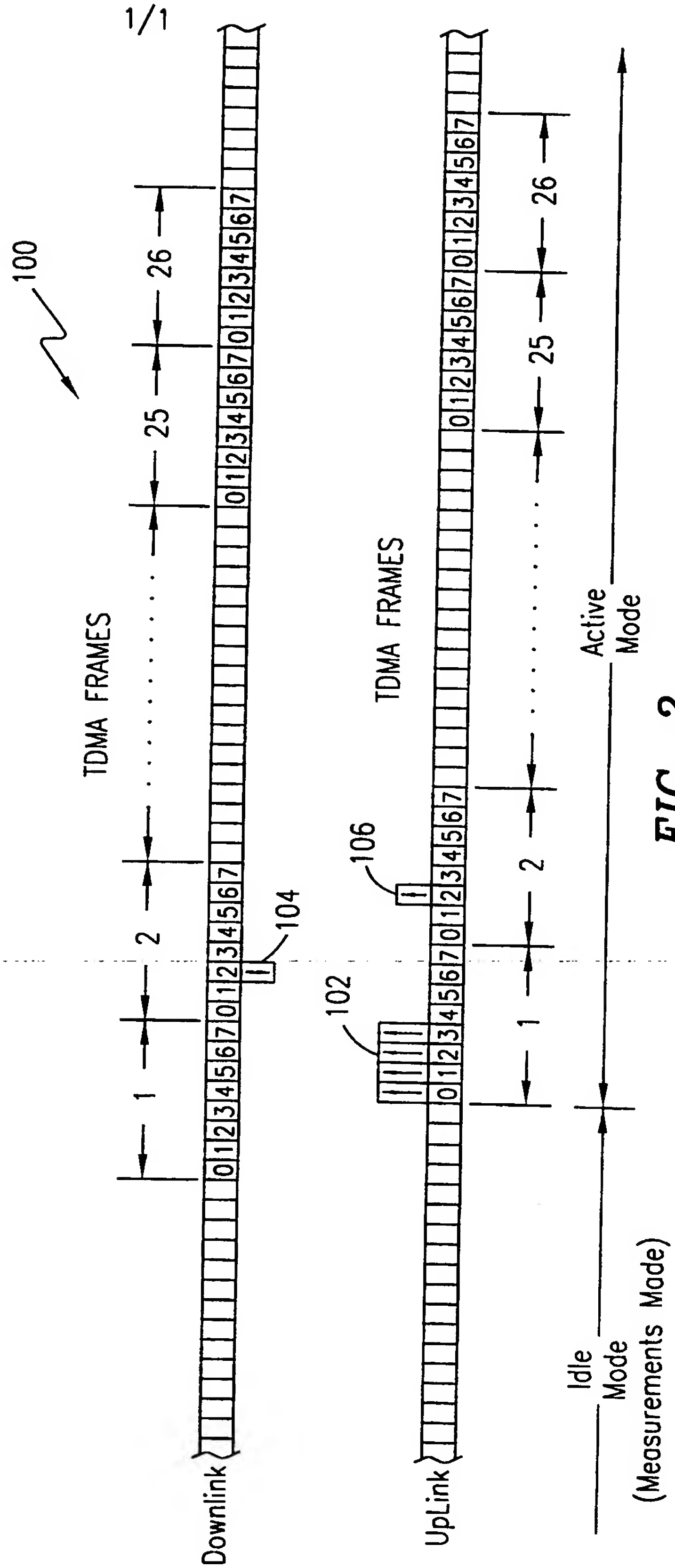
100
Downlink
UpLink
TDMA FRAMES
TDMA FRAMES
1
2
25
26
102
104
106
Idle Mode (Measurements Made)
Active Mode

FIG. 2

# INTERNATIONAL SEARCH REPORT

Inte[illegible]Application No
PCT/[illegible]98/01043

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 H04Q7/34 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

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Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| Y | see column 5, line 66 - column 7, line 7; claims 12,13,18,20-23 | 3,4,7,8 |
| Y | US 5 491 837 A (HAARTSEN JACOBUS C) 13 February 1996<br>see column 5, line 19 - line 37<br>see column 5, line 50 - line 57<br>see column 6, line 66 - column 7, line 4<br>see column 9, line 36 - line 56<br>see column 10, line 7 - line 19 | 3,4,7,8 |
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